Observations on the Insect Parasites of some Coccidæ.

By

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I.—On Aphelinus mytilaspidis Le Baron, a Chalcid Parasite of the Mussel Scale (Lepidosaphes ulmi L.).

With Plates 19 and 20, and 5 Text-figures.

Contents.

Introduction.

The present paper is intended as the first of a series dealing with the biology of the principal insect parasites of certain common British species of Coccidæ. The object of these researches is to ascertain the relative values of such insects as natural controlling agents of a family embracing many species injurious to the operations of man. That certain of the British Coccidæ are extensively parasitised is well known, but the effects of parasitism, as a factor limiting their abundance, has in almost all cases remained unstudied. In some instances it is undoubtedly great, but until the essential features of the relationships between the various species of host and parasites are understood, it is not possible to estimate their value from the economic standpoint. As an example may be mentioned that the second generation of a species of Chalcididæ attacking Lecanium capreæ parasitises the latter to an enormous extent. Its effects on the species, however, is but slight, owing to the fact that it destroys its host as a rule only after the latter has laid most of its eggs. On the other hand, the first generation of the same parasite destroys upwards of 50 per cent. of the Lecanium while the latter is still immature. Judged merely from the external evidences of parasitism, the palm of efficiency would have been awarded to the second generation of the Chalcid.

It has been pointed out (Embleton, 1902, p. 221) that a colony of Coccidæ may be extensively parasitised, and yet betray no obvious manifestation of the fact except to the trained and experienced observer. In such case it may be highly injurious and superfluous to apply insecticides, as they also destroy the beneficial insects which are already acting as a check upon the injurious species. A prevalent belief is that the methods of applied entomology only concern the destruction of injurious insects. An equally important aspect is the investigation of those species which are either directly or indirectly beneficial to the human race.

Aphelinus mytilaspidis Le Baron ranks as one of the principal parasites of the "mussel" scale[1] (Lepidosaphes ulmi L.), and the present paper is intended as a contribution towards a knowledge of its biology and relationship to its host. The investigation has been mainly carried out in the Department of Agricultural Entomology, Manchester University. To Prof. S. J. Hickson, F.R.S., I owe a debt of gratitude for the use of a Zeiss-Greil drawing apparatus and for various other facilities. I am also indebted to Mr. T. J. Young, Principal of the College of Agriculture, Holmes Chapel, Cheshire, for allowing me to carry out field observations on the lands under his charge. Dr. L. O. Howard, Chief of the U.S. Bureau of Entomology, has kindly aided me in the identification of this and other species of Chalcididæ. Also Mr. T. J. Wadsworth, research assistant in my department, has rendered valuable help in the counting and measuring of large numbers of the host mussel scale. Much assistance in procuring material from various localities has been obtained from several sources, and is acknowledged in a later portion of this paper.

Owing to the marked difference in size of the insect in its later stages of the two generations, it is necessary to add that the descriptions of the fully grown larva, the pupa, and the adults were drawn up from observations made on individuals of the first generation.

Remarks on the Biology and Fecundity of the Host.

Lepidosaphes ulmi L.[2] is the commonest of the injurious Coccidæ found in the British Isles. It is nearly world-wide in distribution as a pest of cultivated fruits and nursery stock, and has been largely disseminated through the agency of man. Its favourite food-plant is the apple, but many other species are utilised, Quaintance and Sasscer

[1] Formerly known as Mytilaspis pomorum (Bouché).

[2] The expressions "scale insect" and "mussel scale" are used in this paper with reference to the insect as a whole, while the term "scale" is restricted to its shield-like outer covering.

(1910, p. 5) recording over 118 host plants, and a few more have been added since.

From observations conducted at Holmes Chapel, in Cheshire, during the years 1913–15 it was found that the females commenced to lay their eggs on or about August 17th, and continued oviposition on into September. By the end of October the majority of the parent Lepidosaphes were dead, their scales alone remaining as a protection to the eggs. Newly hatched larvæ were first noticed on May 21st of the following year, and the developmental cycle was completed by the end of July or beginning of August. In Great Britain the insect is single brooded, but there are two broods in certain parts of N. America. No males were met with, and, according to Newstead (1901, p. 198), they are seldom found; parthenogenesis, therefore, appears to be frequent.

The adult female Lepidosaphes vary very considerably in size, and the following observations were made on 75 specimens obtained from three different localities. The size of a scale was judged by its length rather than by the breadth.

Locality.	Food-plant.	Scales examined.	Maximum size.	Minimum size.
Northenden (Cheshire)	Apple	25	2·88 × ·85 mm.	1·63 × ·58 mm.
Warford (Cheshire)	Apple	25	3·07 × ·78 mm.	1·37 × ·65 mm.
Aspley Guise (Beds.)	Apple	25	2·68 × ·72 mm.	1·44 × ·72 mm.

The number of ova laid varies very considerably in different individuals. In America it appears to be much higher than in the British Isles. Girault (1909, p. 357) states that the average number of eggs on poplar in Illinois is 85·6, the numbers varying in different individuals from 48 to 120. Quaintance and Sasscer (1910, p. 2) mention that it varies between 40 and 100. In England, according to my experience, the number is much lower, and from observations made on 75 scales the average found was 37·2 eggs per female. The counts yielded the following figures, the food-plant in all cases being apple :

Locality.	Scales counted.	Eggs present.	Maximum number.	Minimum number.	Average number.
Warford (Cheshire)	25	533	33	10	21·3
Holmes Chapel (Cheshire)	25	1186	66	26	47·4
Aspley Guise (Beds.)	25	1071	62	11	42·8
Totals .	75	2790	66	10	37·2

As a general rule it was found that the size of the parent scale bears some relation to the number of eggs produced. Measurements were made of 30 scales taken at random, and obtained from two widely separated localities. The number of eggs deposited was noted in each case, and the counts were made after the females were dead, thus ensuring that they had laid their full complement. It was found that the largest scales usually sheltered the greatest number of eggs beneath them.

Historical.

So far as I am aware, Fitch (1855, p. 36) was the first to observe what was most probably the Aphelinus parasite in any of its stages. He states that he repeatedly noticed a small, honey-yellow larva, three hundredths of an inch long beneath the mussel scale. He further adds that it is probably the larva of some minute Hymenopterous insect, "specially designed by Providence for destroying the eggs of the bark louse." The perfect insect, he believes, makes its exit by perforating a small round hole through the scales, such holes being frequently met with, and on p. 35 of his Report one of these holes is figured. Walsh (1867, p. 45) refers to Fitch's observations, mentioning that he had also noted round holes in the scales, and similarly regarded them as being made by a parasitic fly, belonging probably either to the Chalcididæ or Proctotrypidæ. Walsh, however, did not observe the yellow larva referred to by Fitch. The adult insect remained undiscovered until three years later, when Le Baron (1870, p. 360) described the female. He gives outline figures of the insect and its larva with some observations on its life-history and habits, and the extent of its parasitism. He concludes that the insect has two broods in the year, and remarks that by the middle of September many of the present year's scales are pierced with round holes, through which the first brood of the Chalcid has escaped; while late in the fall, under about an equal number of scales, the fully-grown larvæ of the second brood are to be found. The second brood, he adds, must appear in the winged state early enough the next summer to deposit the eggs from which the first brood of next year will proceed. He also deals with the insect in his first Report as State Entomologist of Illinois (1871, pp. 34–39). Riley (1873, p. 87) quotes Le Baron's observations, but does not add any new information concerning the insect. The male insect was not discovered until 1881, when it was described by Howard (1881, p. 354), who also mentions that his observations seem to confirm Le Baron in the supposition that there are two broods of the Chalcid in the course of a year. Twenty-eight years later Marchal (1909, p. 1223) published some interesting observations on the process of oviposition and certain habits associated therewith, but I am not aware that any further contributions have been made towards a knowledge of the biology of this insect.

Systematic Position.

The genus Aphelinus is a member of the great group of parasitic Hymenoptera placed by Ashmead (1904) in his super-family of the Chalcidoidea, and in the family Eulophidæ. It belongs to the sub-family Aphelininæ, which are regarded by many authorities as being allied to the Encyrtinæ. Ashmead (loc. cit., p. 344) states that they are clearly a component of the Eulophidæ as is shown by the structural characters of the meso-thorax, and Schmiedenknecht (1909, p. 390) adopts this same view. Morley, in his Catalogue (1910, p. 25), places them between the Encyrtinæ and the Pireninæ.

The Aphelininæ are distinguished by Howard (1895A, p. 6) by the following characters: The mesopleura are divided, the middle legs are not specially developed for saltatory purposes (although the insects jump well), and the first tarsal joint of the middle legs is not incrassate; the antennæ are not more than eight-jointed, and the parapsidal sutures are distinct. The mandibles are small, two to three dentate; the maxillary palpi are three-jointed, and the labial palpi are represented by an elongate tubercle. The antennæ are inserted near the clypeus, and the scape is long and slender. The fore-wings lack the post-marginal vein, and the abdomen is broadly sessile.

The genus Aphelinus was erected by Dalman in 1820, and according to Howard (loc. cit., pp. 23–24) may be separated from other genera of the sub-family by the following characters: The oblique hairless line of the fore-wings is very distinct. The ovipositor is very slightly extruded or is entirely hidden. The fringed apical cilia of the fore-wings are very short; the body is robust, eyes naked in the yellow species and hairy in the black species. The posterior border of the mesocutellum is rounded, and the anterior border is bounded by three straight lines. The antennæ are six-jointed, scape long and slender, pedicel normal, joints 1 and 2 of the funicle very short, joint 3 about as long as or a little longer than the pedicel, club compact, not jointed, subellipsoidal. The middle tibial spur is very pronounced, mesoscutar parapsides rather small, marginal vein very long, longer than submarginal; stigmal and post-marginal short.

Schmiedenknecht (1909, pp. 451–453) catalogues forty-two species of the genus, and additional forms have been described since, making the known species rather more than sixty in number. Of these, Morley (1910, pp. 25–26) catalogues fourteen species as occurring in the British Isles, excluding *A. mytilaspidis*, which was not known to him as a British insect.

Distribution and Habits of the Aphelininæ.

This sub-family is nearly world-wide in range, species being known from almost all parts of the globe, with the exception of the colder temperate and polar regions. *Aphelinus mytilaspidis* occurs in many parts of the United States and Canada, also in France (Marchal, 1909) and in Italy, according to Masi (1911) and Voglino (1913). In the British Isles the only previous record is that of the Duke of Bedford and Pickering (1906, p. 7), who found it at Woburn (Beds.) during the course of their experiments on the effects of insecticides on the mussel scale. During the years 1913–15 I have obtained a large number of branches and twigs of apple attacked by mussel scale and have bred out this Chalcid from the following localities:—Surrey: Kew Gardens, Merton, Oxshott, Cobham, Wisley, and Woking. Devonshire: Plymouth, Bere Alston. Bedfordshire: Aspley Guise. Gloucestershire: Mickleton, Slough. Hampshire: Botley, Bishop's Waltham. Somersetshire: Long Ashton. Worcestershire: Badsey. Leicestershire: Meatham. Shropshire: Newport. Cheshire: Holmes Chapel, Northenden, Northen Etchells. Lancashire: West Didsbury near Manchester. Cumberland: Carlisle. It may be said, therefore, that *Aphelinus mytilaspidis* is generally distributed in England. I have not, however, been able to obtain any records for Scotland or Ireland, but it doubtlessly occurs in both countries.

In their habits the larvæ of the Aphelinæ are either exclusively parasitic, or parasitic and partially predaceous. They may devour both their hosts and the eggs of the latter, and confine their attack almost exclusively to the Rhynchota. Their principal hosts are Coccidæ (particularly the Diaspinæ) and Aphididæ; less frequently they attack the Aleurodidæ. Outside the Rhynchota, Giraud ('Verh. zool. bot. Ges. Wien.,' xiii, 1864, p. 1278) has recorded Aphelinus locustarum (Gir.) from the Orthopteron Xiphidium fuscum, and Rondani ('Arch. p. l. Zool.,' 1870, pp. 12 and 15) has described A. nemoranæ (Rond.) from a Lepidopterous insect, Xylopoda nemorana.

Aphelinus mytilaspidis, in addition to parasitising Lepidosaphes ulmi, has also been recorded, according to Howard (1895A, p. 11), from the following Coccidæ in America: Chionaspis salicis, Diaspis carneli, and Aspiodiotus perniciosus. Girault (1911, p. 184) also records it from the latter host on plum in Illinois. In France, Marchal (1909) mentions it utilising Aspidiotus ostræformis as a host. In Italy, Voglino (1913, p. 1004) mentions it parasitising L. ulmi on Canadian poplar, and Masi (1911, p. 158) records it from Aspidiotus betulæ and A. hederæ in various localities. It Great Britain it is only known from Lepidosaphes ulmi.

The Female.

Coloration.—Pale lemon yellow with the ocelli crimson and the eyes black. The antennæ are yellow with a slight smoky suffusion, and the mandibles and the stylets of the ovipositor are brown owing to their greater degree of chitinisation. The legs are entirely yellow, the wings hyaline, and in some examples they are slightly tinged with yellow. The wing veins are distinctly lemon yellow. In newly emerged individuals the yellow coloration is paler, and the eyes are usually green, not having yet attained their black pigmentation.

The Head.—The head is of about equal width to the thorax, and is invested dorsally with a number of short setæ. The antennæ (Pl. 19, fig. 5) measure ·38 mm. in length and arise from the head a very short distance (·01 mm.) in front of the mandibles. They are seven-jointed, the respective joints being related to one another in length in the proportion of 1 : 14 : 5 : 1 : 1 : 3 : 11. Howard (1895, p. 24) states that in the genus Aphelinus the antennæ are six-jointed. In the present species, however, there is a small though well-defined basal joint (*b.*) which previous writers have regarded as belonging to the scape (*s.*). The eyes are slightly hairy; each hair is very minute and arises from the point where three ommatidial facets are in contact with one another. The ocelli are disposed almost to form the extremities of the sides of an equilateral triangle. The two posterior ocelli are situated nearer to the eyes than to the median and anterior ocellus (Pl. 19, fig. 1). The mandibles (Pl. 19, fig. 4) are relatively stout and measure ·05 mm. long × ·04 mm. wide. They are both similar in form, and each is armed by three teeth, of which the two outer are prolonged obliquely across the jaw in the form of a pair of outstanding ridges. Situated dorsally to the mandibles is a transverse chitinised bar which serves to give rigidity to the anterior margin of the head and support to the jaws. It is more slender than its counterpart figured by Bugnion (1890, Pl. 24, fig. 44) in Encyrtus fuscicollis and is, furthermore, attached to the head skeleton by a pair of backwardly directed arms not referred to by that observer.

The first maxillæ (Pl. 19, fig. 2) are delicate and membranous; each measures ·09 mm. in maximum length and ·02 mm. in width. Its morphology is not clear, but probably the basal portion (*b.*) is to be regarded as corresponding to an undifferentiated cardo and stipes. Arising from it is an undivided lobe (*a.*) bearing hairs along its anterior margin. The maxillary palp (*mx. p.*) is a slender appendage measuring ·03 mm. long and is two-jointed, the joints being related to one another in the proportion of 2 : 3. The second joint is terminated by a slender drawn out seta, longer than itself. The labium (second maxillæ) (Pl. 19, fig. 3) is a small median structure fitting in between the two maxillæ, but not extending so far backwards as the hind margin of the latter. The body of the labium (*m.*) is probably to be regarded as the mentum, and it measures ·03 mm. to ·04 mm. long and ·02 mm. in width. At its distal end it carries a membranous lobe, ·01 mm. long, and apparently representing the ligula (*l.*). The latter structure bears along its anterior margin several, usually four, peg-like organs possibly of sensory function. The labial palpi (*l. p.*) are extremely small and delicate organs and are easily overlooked. They are setiform, ·02 mm. in length, and composed of a single joint terminated by a seta of about equal length.

The Thorax (Pl. 19, figs. 1 and 6).—In describing the sclerites of the thorax I have followed the nomenclature adopted by Howard (1881, p. 352), and also used by him in his Revision of the Aphelinæ (1895).

The pronotum (*pn.*) is narrow and band-like and bears five bristles on either side, the external one being the most prominent. The mesonotum consists of (1) the mesoscutum with its lateral plates or parapsides, and (2) the mesoscutellum, together with the scapulæ. The mesoscutum (*mtm.*) is a large sclerite forming the greater part of the anterior half of the mesonotum. It is armed with five to seven bristles on either side of the middle line, whose arrangement can be readily understood by referring to Pl. 19, fig. 6. When the lower number is present the second bristle from the median line in the anterior row on either side is absent, and likewise the anterior pair of the four bristles occupying the centre of the thorax. The remaining bristles are constant in all specimens that I have examined. The parapsides (*pr.*) form the sides of the mesoscutum; they are very narrow posteriorly, broadening out anteriorly and becoming somewhat laterally extended. They carry a pair of small setæ on their anterior border. The mesoscutellum (*mlm.*) forms the posterior half of the mesonotum; its hind margin is prominently rounded, and it carries a pair of conspicuous backwardly directed dorso-lateral bristles on either side. Its scapulæ (*scp.*) are roughly triangular in form, and extend forwards to the commencement of the lateral widening of the parapsides. Each scapula carries a single small bristle. Arising from the mesoscutellum is an internal chitinous plate, developed from the vertical intersegmental fold between the meso- and metanotum. It is a characteristic feature in many species of Aphelinus, and is best seen in specimens mounted in balsam. This structure also occurs in the Encyrtinæ, and has been probably correctly identified by Bugnion (1890, p. 506) as the mesophragma. It measures ·19 mm. long and ·11 mm. wide, and extends backwards to as far as the second abdominal segment. Its function is to give attachment to the large longitudinal muscles of the thorax. The metanotum (*mn.*) is very narrow and band-like, expanding somewhat laterally on either side. The propodeum (*i. t.*) is about three times the depth of the metanotum, and, similarly to the latter, carries no bristles.

The fore-wings (Pl. 19, fig. 1) are finely pilose except for an oblique hairless tract measuring ·03 mm. in greatest breadth, which extends backwards from the costal margin, just in front of the stigmal vein, to the posterior margin of the wing. On the proximal side of this tract, the fine hairs investing the wing membrane are nearly twice the length of those on the distal portion. They are arranged in seven or more irregular rows disposed more or less parallel to the hairless tract, but are absent from a small area at the base of the wing. The sub-marginal vein is much shorter than the marginal, the post-marginal vein is practically absent, and the stigmal vein small and inconspicuous. Arising from the posterior border of the sub-marginal vein and the base of the marginal vein, is a row of about twenty-two minute rounded peg-like processes (Pl. 19, fig. 7). The marginal hairs are fine and short; they commence at a point on the costal margin where the marginal vein terminates, and extend round the wing to a point almost opposite it on the hind margin. From this position, where the marginal hairs cease to be present, to as far back as the hairless tract (already referred to), the hind margin of the wing is strengthened by the presence of a kind of chitinous rim or thickening (Pl. 19, fig. 1).

In the hind-wings the submarginal vein presents about sixteen projecting points (Pl 19, fig. 8) very similar to those on the fore-wing. The marginal vein is a little shorter than that of the fore-wing, and there is no stigmal vein; at its apex is a pair of hooked hair-like processes which fit into the chitinous rim of the fore-wing and thereby hold the two wings together when in flight. The remaining features of the hind-wings are sufficiently evident on referring to Pl. 19, fig. 1 to need no further reference.

The legs are tolerably long and slender. The fore legs (Pl. 19, fig. 9) are the shortest and differ from the succeeding pairs in having short and somewhat swollen tibiæ. The fore tibia is not as long as the tarsus, and is armed with a single curved spine or spur at its apex. The tarsal joints (excluding the claws) are related to one another in length in the proportion of 5 : 4 : 2 : 2 : 3. The middle legs (Pl. 19, fig. 10) differ in their much longer and more slender tibiæ, which slightly exceed the tarsi in length; they are armed on the inner side of their apices with a prominent terminal spur ·07 mm. long. The tarsal joints are mutually related in length as 8 : 4 : 4 : 2 : 3. The hind legs (Pl. 19, fig. 11) are the longest of the three pairs, and their tibiæ are considerably longer than the tarsi. The tibial spur is small and inconspicuous, measuring only ·02 mm. long. The tarsal joints are related to one another in length as 7 : 4 : 3 : 3 : 5.

The Abdomen.—The abdomen measures on an average ·5 mm. long and is not separated from the thorax by any marked constriction or petiole. It consists of seven evident segments (Pl. 19, fig. 1), of which the first five carry a group of postero-lateral setæ on either side. On the hind margin of the sixth segment there is a complete dorsal band of similar setæ and likewise a band across the middle of the terminal segment. Situated at the base of the apical segment of the abdomen, and fitting into a lateral sinus on the hind border of the preceding segment, is a small sensory plate, ·015 mm. in diameter (Pl. 19, fig. 13). Each plate carries three delicate setæ, of which the longest measures ·12 mm. in length. These plates are very characteristic structures among Aphelinæ and Encrytinæ, and the setæ to which they give basal support are apparently sensory in function. On the ventral aspect of the abdomen the most important structure is the ovipositor (Pl. 19, fig. 12); as it scarcely projects beyond the apex of the abdomen it is frequently invisible dorsally. It consists of the following parts: (A) A pair of extremely fine stylets (*sty.*), ·33 mm. long, each having a diameter of ·002 mm. The two stylets fit together in exact juxtaposition to form a very delicate rigid piercing needle. Basally they divaricate in the form of a letter **V**, and the two arms thus formed ($sty._1$) also curve prominently upwards in the vertical plane. In the preparation represented in Pl. 19, fig. 12, these two curved arms are pressed outwards, so as to lie in the same plane as the other parts owing to the weight exerted by the cover-glass. (B) The sheath (*sh.*) (gorgeret of Bugnion), which takes the form of two very elongate pieces united together in the middle line to form a groove. This groove faces ventralwards, and within it are lodged the stylets. It is practically of the same length as the latter and measures ·013 mm. in width. On the right side its apex is sharply pointed and armed with five extremely minute teeth (Pl. 19, fig. 14). The two parts forming the sheath divaricate basally and are also curved dorsalwards in a manner similar to the stylets. At its innermost extremity each arm of the sheath is fused with a somewhat triangular supporting plate (*t. p.*). The curved portions of the sheath ($sh._1$) are thickened and groove-like, and within each trough so formed lies the arm of the stylet of its side. At its point of bifurcation the sheath is strengthened dorsally by means of a transverse chitinous support or bridge (*c. sh.*), only partially visible from the ventral side. (C) Situated on either side of the sheath is an elongate inner plate ($pl._1$), ·30 mm. long, and movably articulated with the apex of the latter is a single-jointed palp-like appendage (*ap.*). This carries a small number of hairs, some of which being possibly tactile in function. Basally, the inner plate articulates by means of a chitinised area (*s. pl.*$_1$), with the support (*c. sh.*) of the ovipositor sheath. The plate is strengthened by means of a median rib of chitin (*r.*$_1$), and this structure fans out basally to fit in contact with the thickened edge (*sh.*$_1$) of the arm of the sheath of the ovipositor. By means of a concavity near the base of the median rib, the inner plate movably articulates with the rounded inner process of the supporting plate (*t. p.*). (D) Partially overlying the inner plates is a pair of much wider outer plates (*pl.*$_2$) measuring ·22 mm. long and ·1 mm. in greatest breadth. Each outer plate is similarly supported and strengthened by a median rib (*r.*$_2$), which bifurcates into two branches directly from the base. The proximal extremity of the rib is hollowed out to present a surface for articulation with the rounded outer surface of the supporting plate (*t. p.*). Bugnion (1890, p. 514, and y′ in Pl. 25, fig. 52) describes in Encyrtus fuscicollis a third pair of plates or "ecailles chitineuses," which appear to have no counterpart in A. mytilaspidis. The only other account of the structure of the ovipositor in a Chalcid with which I am acquainted is that of Miss Embleton, who studied it in Comys infelix Embl. From a perusal of the authoress' paper it is clear that the ovipositor of Aphelinus agrees more closely with that of E. fuscicollis than with the former species. (E) The supporting plate (*t. p.*) measures ·04 mm. × ·03 mm. and articulates, as already described, with the arms of the ovipositor sheath and the median ribs of the outer and inner plates. It is of great importance as a fulcrum upon which the movement of these parts is effected. I may add that the ovipositor, on account of its minuteness, and its associated parts, on account of their extreme delicacy and transparency, have proved very difficult to investigate. It was not until after more than thirty preparations had been made, by various methods of technique, that it was found possible to understand the relations of the different parts connected with it.

Size.—The following measurements were made from two average-sized examples taken from each generation. It will be noted that there is a relatively marked difference in size between individuals of the two generations. Out of forty examples of the second generation (from two localities) the largest measured ·67 and ·77 mm. in length respectively. The wing measurements in all cases include the marginal hairs.

	First generation.		Second generation.	
Length to apex of ovipositor	·93 mm.	·83 mm.	·55 mm.	·59 mm.
Length of head and thorax	·44 ,,	·40 ,,	·26 ,,	·29 ,,
Length of abdomen	·49 ,,	·43 ,,	·29 ,,	·30 ,,
Breadth of thorax	·36 ,,	·28 ,,	·23 ,,	·20 ,,
Length of fore-wing	1·02 ,,	·81 ,,	·59 ,,	·59 ,,
Width of fore-wing	·36 ,,	·33 ,,	·27 ,,	·19 ,,
Length of hind-wing	·72 ,,	·68 ,,	·44 ,,	·49 ,,
Width of hind-wing	·17 ,,	·17 ,,	·11 ,,	·15 ,,
Expanse of fore-wings from tip to tip	2·40 ,,	1·90 ,,	1·41 ,,	1·38 ,,

The Male.

The male is very much rarer than the female, a feature which is of common occurrence among the Chalcididæ. Out of over 750 specimens bred between May, 1914, and September, 1915, I only obtained ten male individuals. Dr. L. O. Howard (1881, p. 354) was the first to describe the male of A. mytilaspidis, and he mentions that it is so similar to the female as to be indistinguishable from the latter unless the genitalia be examined. The males are generally smaller in size than the females. The joints of the antennæ are mutually related in length in the proportion of 6 : 27 : 13 : 3 : 3 : 7 : 23. In most examples the scape is a little shorter than in the female, and Howard states that the club of the antenna is more truncated at its apex. The genitalia (Pl. 19, fig. 15), however, are the only organs to which it is necessary to refer in any detail. From the apex of the penis to the base of its associated parts the genitalia measures ·13 to ·15 mm. in length.

The penis (*p.*) is a cylindrical organ ·068 mm. long and ·015 mm. in greatest diameter. At its apex it is provided with about eight minute papillæ (*p. p.*). Bugnion (1890, Pl. XXV, fig. 51, p. 511) has figured very similar structures in Encyrtus fuscicollis, and regards them as being sensory in function. Miss Embleton, in her study of Comys infelix (1904, p. 251, Pl. 12, fig. 45), mentions that the penis in that Chalcid has minute papillæ which are the openings of the ducts leading from the gonads. They are situated in a very similar position on the apex of the penis as the papillæ referred to herewith. The sides of the penis are strengthened by a pair of flattened chitinous rods (*r. p.*), which are continued forwards into the basal portion of the genitalia. Arising near the base of the penis is a pair of claspers (*c.*) or "harpons mobiles" (Bugnion); these structures measure ·068 mm. in length, and each carries at its apex a minute outwardly directed tooth. Both the penis and claspers are attached to an unpaired basal portion into which the penis can be partially withdrawn. Ventrally near the bases of the claspers is a pair of minute papillæ (*v. p.*), each surmounted by a small seta.

During copulation the penis and claspers are protruded beyond the apex of the abdomen and introduced into the genital orifice of the female. By means of the contractions of muscle fibres situated at the base of the claspers the latter organs are drawn far apart so as to form a wide V with one another. In this way they apparently function in maintaining the penis within the genital aperture of the female.

The following measurements were made on a typical specimen; those concerning the wings include the marginal fringe of hairs:

Length to apex of abdomen	·8 mm.
Length of head and thorax	·4 ,,
Length of abdomen	·32 ,,
Breadth of thorax	·29 ,,

Length of fore-wing . . .	·8	mm.
Breadth of fore-wing	·27	„
Length of hind-wing	·69	„
Breadth of hind-wing	·19	„
Expanse of fore-wings from tip to tip .	1·89	„

Movements and Reactions to External Stimuli.

The adult insect moves from one portion of a branch to another almost entirely by running; when disturbed it may leap to a distance of $1\frac{1}{2}$ to $2\frac{1}{2}$ in., its progress being aided by the wings, but true flight, in the ordinary sense of the term, seems to be seldom resorted to. Owing to the limited powers of migration of the winged insects, parasitised scales frequently occur in patches on the branches, and for this reason it is necessary to examine a large number of twigs and branches to form an accurate estimate of the degree of parasitism present. The migratory powers of the insect are, therefore, extremely limited. The chief agent in distributing the parasite from one tree to another is wind, which is also the principal factor in spreading the young larvæ of the host.

The insect avoids darkness and instinctively steers its course towards the light, being therefore positively phototrophic. It is in virtue of this habit that examples, which emerge in darkened breeding cages, congregate within the glass tubes inserted in the sides of the latter as described on p. 247, thus affording a ready method of collecting them. They do not exhibit marked response to geotropism, and parasitised scale insects are not restricted to the apices or other portions of a branch. Tower (1914, p. 432) states that *Prospaltella perniciosi*, a parasite of the San Jose Scale (*Aspidiosus perniciosus* Comst.), exhibits both positive phototropism and geotropism, and that scale insects situated on the smaller and outermost branches and twigs are well parasitised. A large number of Chalcids are known to fly towards the light when reared in breeding cages, but Miss

Embleton (1904, p. 235) states that Comys infelix is negatively phototrophic, and the Proctotripid, Eumicrosoma benefica Gahan, according to McColloch (1915, p. 260), also exhibits a similar reaction.

Parthenogenesis.

A notable feature in the biology of this Chalcid is the great scarcity of males, only ten being bred from among over 750 specimens. This fact naturally suggested the probability of parthenogenesis occurring in the species. In order to ascertain whether it obtained or not, seven mussel scales each sheltering a pupa of the Aphelinus were isolated in separate phials. When the adults emerged they were transferred to freshly cut twigs of apple, bearing numerous examples of the host in its younger stages. These twigs were enclosed in glass tubes and the Chalcids were observed under a binocular microscope depositing their eggs beneath the scales on the same day (July 17th, 1915). Five of these eggs (laid by three separate females) were transferred to watch-glasses and kept under close observation in a moist chamber. Four of the eggs hatched in from nine to eleven days in the laboratory at an average temperature of 63° F., and one of the resulting larvæ is represented on Pl. 20, fig. 20. It is noteworthy that Quayle (1910, p. 461) has recorded parthenogenesis in Aphelinus diaspidis and found no males in that species. Parthenogenesis is also known to occur in other Chalcididæ, and it is probably of wide occurrence in that family.

Oogenesis.

In specimens freshly killed, by means of chloroform vapour, the ovaries can be dissected out with comparatively little difficulty. Each ovary (Pl. 20, fig. 22) measures on an average ·4 mm. in length and consists of five ovarioles, though the latter number is not absolutely constant. The oviduct (*od.*) is extremely short and unites almost immediately with its fellow of the opposite side to form a median unpaired vagina. Each ovariole is invested externally with a very delicate membranous coat (*w. o.*), in which nuclei are only discernible here and there. The ovariole ends distally in a germarium or terminal chamber (*g.*) containing a small number of rounded undifferentiated cells. Lower down, the ovariole exhibits a differentiation into egg chambers and nutritive chambers. In the egg chambers (*e. c.*) certain of the cells enlarge greatly, yolk material accumulates therein, and they become clearly marked out as future eggs. Each is surrounded by a layer of follicle cells. Alternating with the egg chambers are groups of smaller cells with prominent nuclei and bearing considerable resemblance to the cells of the germarium. These aggregations of cells constitute what are usually regarded as nutritive chambers (*n. c.*). Still further down, the nutritive chambers are no longer in evidence, and we find a succession of eggs (usually three) in later phases of development. The yolk has greatly accumulated in their protoplasm, obscuring the germinal vesicle from view, the latter being only discernible after treatment with appropriate reagents. The follicle cells at this stage having subserved their function are no longer in evidence, the eggs lying free within the ovariole.

In general structure, therefore, the ovarioles pertain to the meroistic type, in which the ovarian and nutritive (or vitellogenous) chambers alternate with each other. Such a method of arrangement is the rule among the majority of Hymenoptera. The largest ovarian eggs measured ·20 mm. in length and ·05 mm. in greatest breadth; they are elongate oval in shape, often somewhat constricted in the middle (Pl. 20, fig. 22). An attempt was made to compute the number of eggs capable of being laid by each female, from an examination of the ovaries. In certain of the Cynipidæ, for instance, the eggs attain maturity very nearly at the same time, which lends value to this method of estimation. In the present species, however, it has been found to be unreliable, as the eggs mature in succession from the bases of the ovarioles upwards. It may be stated, however, that not less than thirty eggs are produced in the two ovaries, but probably double that number is nearer the correct average figure. The fecundity, nevertheless, is relatively low, and it is a well-known fact that in most insects the number of eggs which develop is considerably in excess of those which are actually laid.

Oviposition.

Oviposition was observed from July 10th to 14th in 1914, and from July 15th to 19th in 1915, both in the laboratory and out in the field. For the purpose of noting the details of the process, bred females were transferred to small, freshly cut branches of apple, which were abundantly attacked by the mussel scale. The whole course of oviposition may then be readily observed under a Zeiss binocular microscope. The insects were seen running actively along a branch searching for suitable hosts wherein to deposit their ova. They surveyed the surfaces of likely scale insects by means of a kind of tapping action of the antennæ, and when an apparently suitable host was found, a closer examination followed as a preliminary to the actual process of egg-laying. When the latter commences, the insect directs its abdomen towards the scale with its head pointing outwards—it seldom takes up a position parallel with the length of the scale. The wings are folded over the back, the long axis of the insect is inclined slightly upwards, and the legs are extended backwards. The antennæ are no longer in activity and hang downwards in front of the face. The movable appendages of the inner plates of the ovipositor (*ap.*, in Pl. 19, fig. 12) first come into use, and appear to play a part in selecting the actual place where the perforation of the scale is to occur. When the ovipositor comes into work, the stylets and sheath together form a piercing dart with which the insect makes a minute hole in the scaly covering of the host. After an opening is made, the sheath of the ovipositor is withdrawn, leaving the stylets *in situ*. At first the body of the insect undergoes a slow backward and forward motion, but the final act is almost motionless to the observer. The stylets are so far inserted that the ventral side of the abdomen is in contact with the surface of the scale. The eggs are apparently forced down the incomplete canal formed by the stylets by means of the contractions of muscle fibres situated in the walls of the oviducts. Probably their passage is facilitated by the secretion of certain associated glands which may act as a lubricant, but it has not been possible to definitely verify this suggestion.

Each individual act of egg-laying may last from about fifty seconds up to as much as ten minutes; about six minutes may be taken as the average time occupied in the process. One female was observed to execute as many as eight apparent acts of oviposition in one scale insect, each act involving perforation of the outer covering of the latter in a fresh position. As the result, however, only one egg was found to have been deposited. Five and six perforations were also noted on other occasions, but in not a single instance was there more than one egg deposited in association with each host. Frequently the process of oviposition was apparently gone through and no egg laid, the insect having found the particular host selected unsuitable for some reason. It is evident, therefore, that the antennæ only function in making a preliminary survey of each host, and that it requires the insertion of the ovipositor to finally decide whether the selection has been opportune or not.

The egg is invariably laid beneath the scale on the body of the host and not *within* the latter, the scaly covering alone being perforated. It may be placed either on the dorsal or ventral surface of the host, and was never found adhering to the scaly investment of the latter. Hosts which have recently undergone ecdysis are, in my experience, invariably selected; the exuvium is then lying free from the body, and the new cuticle is still thin and colourless. Such hosts appear white to the eye, and in no instance did the Chalcid select an example whose cuticle was becoming slightly brown and the hardening process setting in preparatory to ecdysis. The average size of the scale selected is about

·8–1 mm. long and ·4 or ·5 mm. broad. Hosts much smaller than this, however, though in other ways apparently suitable, were never selected. Most probably they would provide too little sustenance for the parasitic larva. Out of 324 scale insects of the size usually selected by the Aphelinus for the purposes of oviposition, 254 had turned brown, and no ova of the parasites were found in association with them. The remaining 70 insects were white with a thin and transparent cuticle, and of these 41 carried an egg or young larva of the parasite. The above observations agree in essential points with those of Quayle (1910, p. 399) made upon Aphelinus diaspidis How., a common parasite of the red or orange scale (Chrysomphalus aurantii Mask.) in America.

Marchal (1909, p. 1223) has made some interesting observations on the egg-laying and other habits of A. mytilaspidis, the host in this instance being another species of Coccid, viz., Aspidiotus ostreæformis. He states that he has seen this Chalcid pierce the same Aspidiotus eight times, and each time apply its head to the wound to lick the liquid that issued. "It is very certain," he adds, "that each thrust of the ovipositor does not correspond to the deposition of an egg." Howard (1910, p. 257) summarises the evidence of four different observations, upon four different species of parasites and hosts, dealing with this curious habit of Chalcids feeding at puncture holes made by the ovipositor. He suggests that it seems more probable that the habit will be found to be widespread. With reference to Howard's suggestion, I kept watch over a number of females of the Aphelinus and observed the curious trait described by Marchal. One example pierced an individual scale six times, and after each act applied its mouth-parts to the perforations. Whether the body of the host was actually pierced, and it imbibed any liquid or not, I am unable to say, as the attitude assumed by the insect precluded exact observation on this point. This act was noted in two other specimens, and it is noteworthy that all three were freshly emerged individuals and had probably not previously taken any nutriment. I may add that these same three insects subsequently laid several eggs, and did not afterwards repeat the act just described during the time I had them under observation. Quayle (1910, p. 400), in his account of Aphelinus diaspidis, mentions that it was only on two or three occasions that he observed any indication of this habit. He remarks that it was not certain whether the Chalcids fed at the puncture hole or sealed it, and at any rate it cannot be counted a common habit with that species. An apparently similar habit has been observed by Newstead (1903, pp. 66 and 251) in a Chalcid of the genus Blastothrix, probably B. sericea, which lays its eggs in Pulvinaria vitis, var. ribesiæ. This author remarks that when a suitable host was found "the parasite turned its head towards the anterior extremity of the Coccid and, resting with all its feet upon the body of the latter, inserted its ovipositor into the centre of the thoracic area; it then slowly moved its abdomen up and down, and apparently laid its eggs in the puncture; the parasite then withdrew its ovipositor, and, turning round abruptly, feeling its way again with its antennæ, seized with its jaws the lips of the wound made by the ovipositor, and distinctly closed them upon it and apparently pressed the edges together; finally it passed the palpi over the wound, and then left the coccid to its fate. I subsequently saw the process of ovipositing repeated by three individuals, each one acting precisely the same as the first."

The Egg.

The eggs vary in size from ·13 to ·15 mm. in length and from ·06 to ·11 mm. in diameter. They are oval in shape (Pl. 20, fig. 21) and pale yellowish white in colour. The surface of the chorion is smooth and glistening, and at one pole of the egg is a somewhat shrivelled hooked process. In the laboratory, the average time taken before hatching by eggs laid by females of the first generation, was nine to eleven days. When viewed by means of transmitted light the chorion is sufficiently transparent to allow of the inner contents being clearly seen. Two days or so before hatching the egg swells slightly in size, and the young larva can be clearly seen within. Its mandibles were observed occasionally undergoing movement, and the main lateral tracheal trunks, together with the spiracles, are visible under a high power magnification.

The Newly Hatched Larva.

The larva on emergence from the ovum is nearly spherical in form when viewed from above, and is somewhat flattened in the dorso-ventral plane. In size it averages ·17 mm. in length and ·15 mm. in greatest breadth. It is pale yellowish in colour and is clearly divisible into a head region and thirteen segments (Pl. 20, fig. 20). The mid-gut (*m. g.*) contains a considerable amount of residual food yolk and is clearly discernible as a dark central area. Eight pairs of spiracles are present, and they are situated on the same segments as in the fully developed larva. The tracheal system consists of a main lateral trunk running down either side of the body (*m. t.*), an anterior and posterior commissure (*a. c.* and *p. c.*), and a transverse tracheal branch (*t. t.*) leading from each spiracle to the main lateral trunk of its side. None of the smaller tracheal branches of the older larvæ were to be observed. The mandibles are very similar in form to those of the fully grown larva, but are correspondingly smaller in size. The fat-body is very little developed, and consequently the young larva is more transparent than the later stages. In other essential details of structure it differs very little from the older larvæ, with the exception of the absence of the conspicuous imaginal discs.

The Fully Grown Larva.

Coloration.—Fully developed larvæ are uniformly bright lemon yellow with a faint greenish tinge in some specimens. The mid-gut or stomach shows through the body-wall as a conspicuous oval sac, and appears pale brown in virtue of the ingested food contents. The cuticle is colourless, smooth, and shining.

Size.—From measurements made on a dozen fully grown larvæ, the latter were found to vary in length from ·56 to ·96 mm., and from ·48 to ·60 in maximum breadth. Their average size is ·8 mm. long and ·5 mm. broad.

External Morphology.—In shape the larva is broadly oval and slightly flattened; when fully extended it tapers slightly towards both extremities, but more especially at the posterior end. It is divisible into a head and twelve complete segments, with no differentiation into thoracic and abdominal regions (Pl. 20, figs. 17 and 18). There is a diversity of statement with regard to the number of segments in the larvæ of Aphelinus. Quayle (1910, p. 398) states that in A. diaspidis How. there are "fourteen indistinct segments including the button at the tip." In A. mytilaspidis, Howard (1881, p. 354) states that the dividing lines of twelve segments can be observed with some difficulty. From observations made on sixteen larvæ I find twelve segments to be constant in every instance. The first two segments are the broadest, the anal segment is the smallest, and the intervening somites are sub-equal. The head is much modified, antennæ and eyes are absent, and its most prominent organs are the mandibles (Pl. 20, fig. 19). These structures are minute objects measuring ·01 mm. from apex to base, and approximately the same in breadth across the widest part. They are of the usual form common to Chalcid larvæ and can be withdrawn within the pharynx. They are adapted solely for piercing the eggs or tissues of the host and maintaining a hold thereon. The mouth (*mo.*) is surrounded by a somewhat thickened chitinous rim, and along the upper portion of the latter is a row of six minute papillæ (Pl. 20, fig. 19). There are also a series of five larger papillæ (*pp.*) on either side of the antero-ventral region of the head.

There are eight pairs of spiracles (Pl. 20, fig. 18), the first pair being situated on the anterior border of the first segment. The second segment contains no spiracles, but a pair is present on each of the seven succeeding segments. The spiracles are exceedingly simple in structure, being merely funnel-like depressions of the cuticle receiving the tracheæ at their inner and narrower ends.

Internal Morphology.—As it is not my object to deal with this species anatomically, only a few features of its internal structure will be referred to. The tracheal system is well developed, but its tubes are of extremely narrow diameter. A pair of main lateral tracheal trunks (*m. t.* in Pl. 20, fig. 18) are present, and they differ but little in their calibre from that of their principal branches. The two main trunks are united with one another by a transverse commissure (*a. c.*) situated in the first segment of the larva, and by means of a posterior commissure (*p. c.*) situated in or near the ninth segment. From each spiracle a relatively long and narrow trachea (*t. t.*) passes to the main trunk of its side, and at the point of junction an inwardly directed branch (*v. t.*) passes to the ventral region of its segment. Arising from the branch *v. t.*, or in some cases at the point where it joins the main lateral trunk, is a second branch (*d. t.*), which is mainly dorsal in its distribution. The head receives its tracheal supply by means of a pair of branches originating from the anterior transverse commissure.

The digestive system is extremely simple (Pl. 20, fig. 18). The mouth leads into the pharynx, which passes into a very short œsophagus. At the point where the latter joins the mid-gut or stomach a simple valve is present. The mid-gut is an extensive ovoid sac occupying a large proportion of the hæmocœlic space. The hind-gut passes directly to the posterior extremity of the body, and at its commencement are placed two Malpighian tubes. A pair of salivary glands are present, and their two ducts converge and unite in the first segment, and the main duct so formed passes along the mid-ventral line of the head, beneath the œsophagus, to open on the floor of the mouth (Pl. 20, fig. 19).

The nervous system consists of a brain or supra-œsophageal ganglion, an infra-œsophageal ganglion, and a ventral nerve cord. The latter is a relatively thick linear structure, and exhibits no obvious differentiation into ganglia and connectives.

The fat-body (Pl. 20, fig. 18) is very extensively developed. It is markedly lobulated, and occupies almost the whole of the hæmocœlic cavity between the body-wall and the alimentary canal. It contains a large number of bright yellow globules apparently of a fatty nature, and it is to their presence that the yellow coloration of the larva is mainly due.

The Pupa.

Coloration.—Dorsally the pupa is lemon colour with a slight greenish tinge. The anterior portion of the head, the frontal margin of the thorax, and the fore-wings are smoky. Ventrally the head, antennæ, wings, thoracic sterna, and legs are smoky, and also the developing abdominal plates. The remainder of the pupa is lemon yellow. As development proceeds the smoky coloration extends and deepens to black.

Size.—In length it measures 1 mm. and ·48 mm. in greatest breadth. Owing to being greatly flattened in the dorso-ventral plane the distance between the upper and lower surfaces is reduced to ·2 mm.

Morphology.—On its dorsal aspect the pupa exhibits but few distinguishing features. It is divisible into head, thorax, and abdomen; the numerical proportions in length of these regions are respectively as 2 : 3 : 7. The only head appendages visible are the antennal sheaths, which project slightly laterally. The thorax consists of but a single segment, and exhibits none of the subdivisions seen in the perfect insect. The sheaths of the fore-wings extend backwards to the second abdominal segment, but only the base of the sheaths of the hind-wings are visible. The abdomen is divisible into seven segments, whose limits can only be made with difficulty.

Viewed from the ventral aspect, the following features are most noticeable (Pl. 20, fig. 16). The antennal sheaths (*an. s.*) are elbowed and two-jointed; they extend on to the thorax and lie between the proximal portions of the first two pairs of legs, separating the latter from each other. The bases of the antennal sheaths are placed widely apart, the internal being equal to about half the width of the head. The mandibular sheaths (*md. s.*) lie between the bases of the sheaths of the antennæ, on the same level with the latter. The maxillary sheaths (*mx. s.*) are in contact with each other basally and diverge in a V-shaped manner. Each is two-jointed, the distal joint being very narrow and truncated. The labial sheath (*lm. s.*) lies in the space between the diverging sheaths of the maxillæ and is bounded by the latter. It is subtriangular in form, and in contact with it is a pair of very small distal sheaths which enclose the developing labial palpi.

In the thorax the sterna are very conspicuous as a pair of large bilobed plates occupying the greater part of the mid-ventral area. The sheaths of the fore-legs ($l._1$ *s.*) are single-jointed, and their basal attachment is situated very far forwards. The sheaths of the middle pair of legs ($l._2$ *s.*) are, in most specimens, two-jointed, and a prominent inward projection encloses the long tibial spine of the adult. The sheaths of the hind-legs ($l._3$ *s.*) are very elongated and reach backwards to the penultimate segment of the abdomen. The proximal half of each sheath is entirely concealed by the sheath of the fore-wing of its side. The sheaths of the fore-wings (*f. w.s.*) extend posteriorly as far as the frontal border of the second abdominal segment, almost entirely concealing those of the hind-wings (*h. w.s.*), only the apices of the latter being visible. The abdomen does not offer any special characters for description; the most conspicuous feature is the developing ovipositor in the case of the female and the penis in the male.

The foregoing description refers to pupæ of the first generation; those of the second generation are markedly smaller in size, averaging ·64 to ·7 mm. in length and ·28 to ·31 mm. in maximum breadth, but do not differ in any other respect.

Life-History.

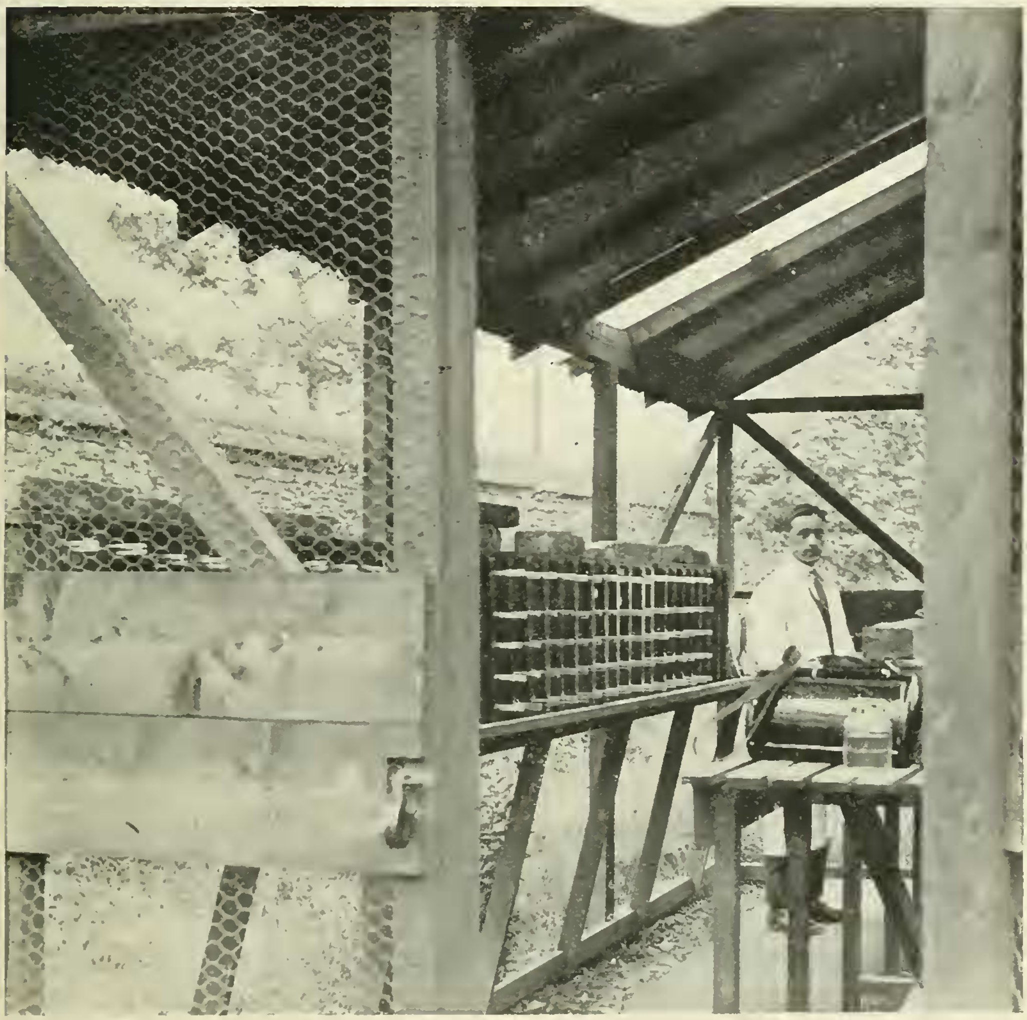
Material and Methods.—In order to ascertain the distribution of the Chalcid and the extent of its parasitism, branches of apple infected with the mussel scale were obtained from various parts of England. These were cut up into convenient lengths and placed in breeding-cages. Wherever desirable, the cut ends of the branches and twigs were sealed up with wax. It is obvious that this method is only effective from about the end of September until the commencement of the following May, when the host is in the egg stage and is not dependent upon living plant tissues for its sustenance.

In obtaining an adequate supply of the mussel scale from as many localities as possible I have been generously aided by Mr. J. C. F. Fryer, Entomologist to the Board of Agriculture. Further material was also sent by Messrs. P. Hedworth Foulkes, A. S. Horne, W. Laurance, W. H. Nield, A. G. L. Rogers, J. T. Wadsworth, C. B. Williams, B. L. Wolf, and others, to all of whom my thanks are due. Mr. A. Calderbank, of the Holmes Chapel Agricultural College, has also aided me in various ways.

In order to rear and breed out the Aphelinus under as nearly as circumstances allow to natural conditions an open insectary was utilised (Text-fig. 1). This structure was erected in the Manchester University Biological Experiment Ground at Fallowfield. It is constructed of wood, with a galvanised corrugated iron sloping roof. Two glass skylights were let into the latter in order to admit a certain amount of light from above. It measures 20 ft. long, 9 ft. wide, and 10 ft. high to the centre of the ridge of the roof. Apart from the framework, the walls and door of the insectary are entirely open to the weather, only being protected by wire rabbit netting of large mesh.

Twenty-three breeding cages were utilised. Each cage was constructed in the form of a tall wooden box, measuring 39·5 cm. by 23 cm. and 73·5 cm. high (Text-fig. 2). For the purpose

TEXT-FIG. 1.[1]



View of the interior of insectary: on the tabling to the left-hand side is seen a row of breeding cages used in rearing *Aphelinus mytilaspidis*.

of attracting the insects towards the light and collecting them as they emerged, ten round holes were made in its front wall, and into each of these apertures a glass tube, 10 cm. long and

[1] I am indebted to Mr. J. T. Wadsworth for taking the photographs reproduced in Text-figs. 1–5.

1·6 cm. in diameter, was inserted. Each cage was closed by a closely-fitting sheet of glass resting on an inner ledge,

TEXT-FIG. 2.

A breeding cage used in rearing Aphelinus mytilaspidis. About one eleventh actual size.

situated just below the opening of the box, and light was excluded by means of a wooden lid. The cages were elevated from the surface of the tabling upon which they stood by means of wooden squares, 1·5 cm. in thickness. In the middle of the floor of each box an aperture, 6·25 cm. square, was cut;

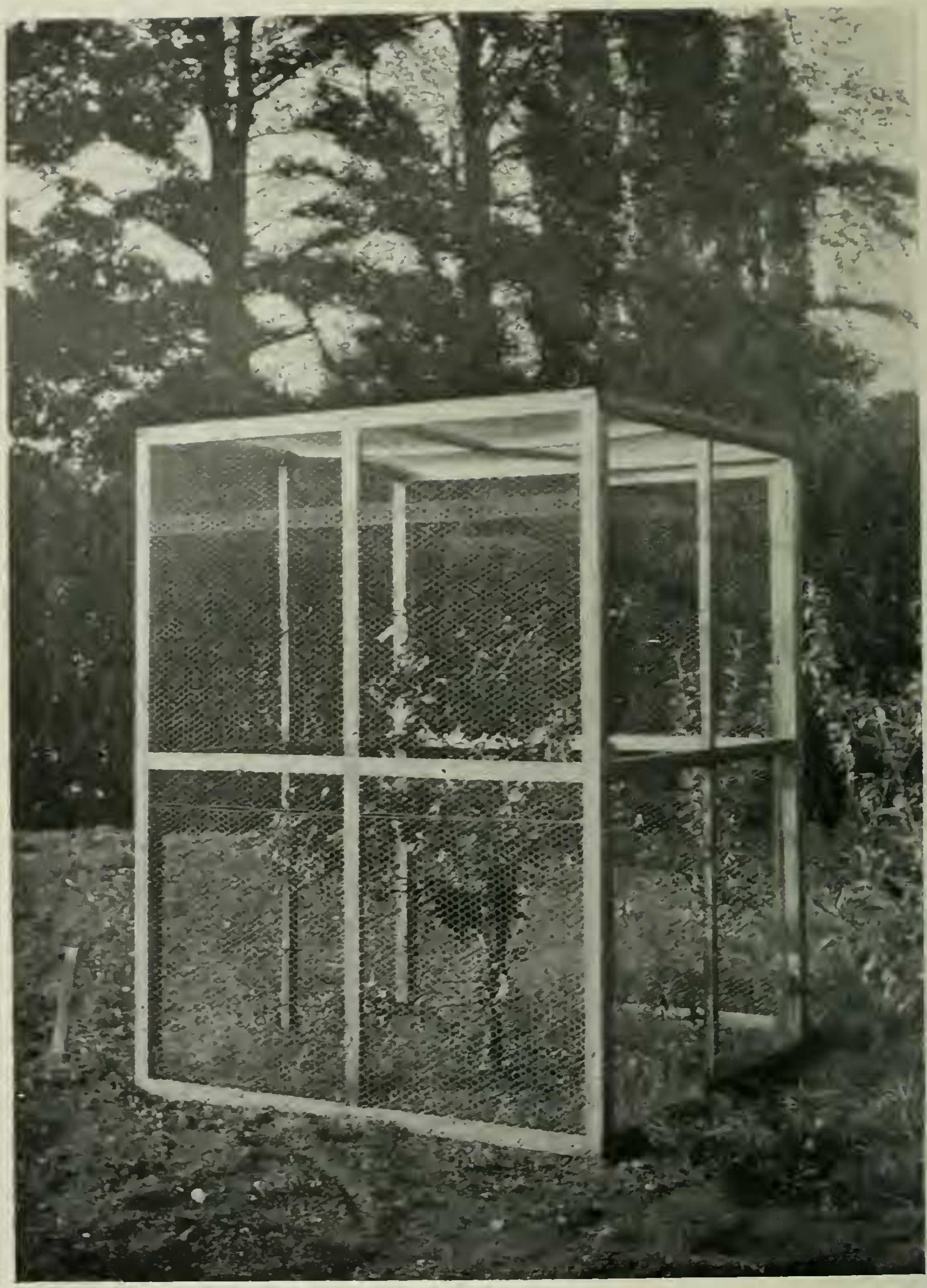
this was closed by a piece of very fine bolting silk whose meshes averaged ·06 mm. across. By this means a certain amount of air was admitted into the interior of the cage, but at the same time only a negligible amount of light could enter, and the escape of any parasites was effectively precluded. By the time the last insect had emerged in each cage, a small amount of débris had accumulated on the floor of the latter. This was collected and examined under a binocular microscope for any dead Chalcids it might contain. From twenty-three cages it was found that only thirteen *A. mytilaspidis* failed to find their way into the glass tubes—a much lower proportion than had been anticipated.

In order to carry out field observations, and to ensure an adequate supply of material at every stage for laboratory work, three cages were erected over selected apple trees on the lands belonging to the Agricultural College at Holmes Chapel (Cheshire). These were constructed of a wooden framework, and across their sides and roof was stretched wire rabbit netting, in order to exclude tits and other birds which prey upon Coccidæ. Two of the cages were erected in a tolerably open though sheltered situation (Text-fig. 3), and the remaining cage was constructed against a warm south wall (Text-fig. 4), which is a situation specially favoured by scale insects.

On account of the extensive use of nicotine spraying very few of the trees on the lands of the Holmes Chapel Agricultural College were found to be attacked by the mussel scale. For the purpose of following the life-history of the parasite, four perfectly clean young trees were infected on April 30th and May 21st, 1914, with parasitised material obtained from Aspley Guise (Beds.) and Newport (Salop). The host rapidly spread over its food plants, especially in the case of the trees shown in Text-fig. 4, and the parasite was found to have thoroughly established itself. It maintained its existence through three generations, after which no further observations were conducted.

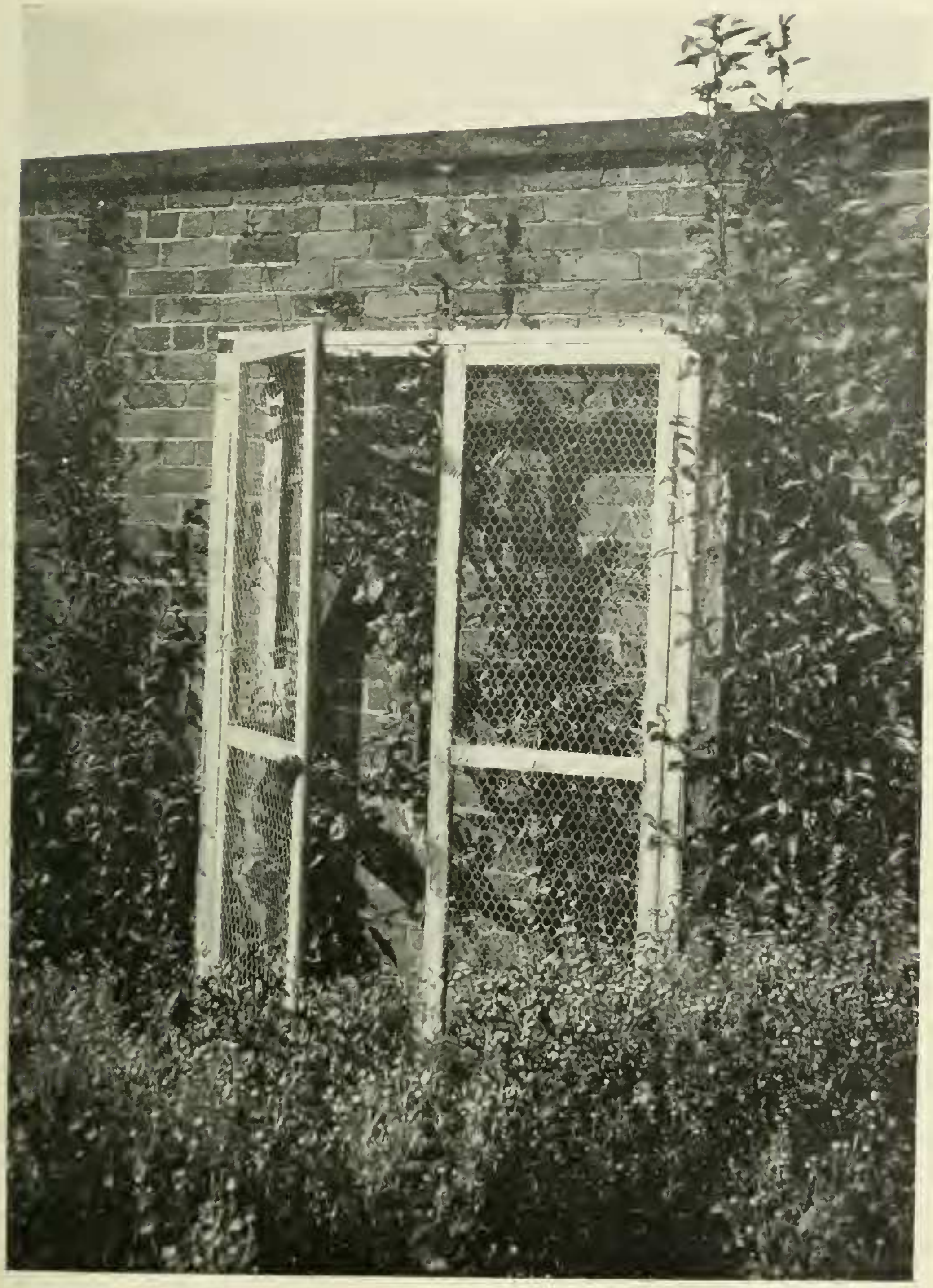
The First Generation.—The first generation of the

TEXT-FIG. 3.



Cage at Holmes Chapel (Cheshire) used for screening apple trees bearing the mussel scale and its parasite. It measures 5 ft. 6 in. square and 7 ft. in height.

TEXT-FIG. 4.



Cage at Holmes Chapel (Cheshire) erected against a south wall over apple trees bearing the mussel scale and its parasite. The cage measures 4 ft. 6 in. long, 7 ft. high, and 1 ft. deep.

Chalcid of each year are derived from larvæ which have passed through the winter beneath fully-grown mussel scales. When the time for emergence arrives, the parasite cuts an

TEXT-FIG. 5.

A group of mussel scales (Lepidosaphes ulmi) in situ on a branch of apple. About half of the scales show emergence holes made by Aphelinus mytilaspidis (first generation). × 8.

aperture in the scale by means of its mandibles, and thereby effects its escape into the outer world (Text-fig. 5). These emergence holes can be seen with the unaided eye, and are seldom totally absent from any colony of the mussel scale.

Their position on the scale varies, and is dependent upon whether the pupa of the parasite lay with its head directed towards the anterior or posterior extremity of the scale. In those cases where the pupal head was directed anteriorly, the emerging Chalcid usually made the hole about the middle or nearer to the anterior end of the scale. On the other hand, if the pupa lay with its head directed towards the broad end of the scale, the emergence hole was situated nearer that extremity of its host.

The first generation consists almost entirely of females. Out of over 700 examples reared from various localities, only four were males. These four specimens were bred out singly from four different localities on the following dates during the year 1914: Aspley Guise (Beds.), July 2nd; Cobham (Surrey), August 11th; Oxshott (Surrey), June 4th; Newport (Salop), July 25th. Records were kept of the approximate dates of emergence of 681 females reared from material obtained from fifteen different localities. They commenced appearing in the breeding cages from May 24th, and continued emerging until August 9th; over 79 per cent., however, appeared between June 21st and July 8th. The primary factors which cause the times of emergence to vary between such wide limits I have been unable to definitely discover. The prevailing climatic conditions certainly exercise a marked influence, especially upon the pupa, and a good deal also depends upon the time when the larvæ became full-fed, some of the latter pupating very much later than others. Reproduction takes place almost entirely by means of parthenogenesis. In Lancashire and Cheshire egg-laying occurs principally during the first three weeks of July. On hatching the young larvæ attach themselves to the body of their hosts, and remain as external parasites during the whole of that period of their existence. They maintain a firm hold on the cuticle of the host by means of their sharp-pointed mandibles, and gradually imbibe its juices until they become full-fed. The nutriment appears to be entirely absorbed by means of a combined sucking and pumping action of the pharynx and œsophagus. Parasitised hosts undergo no further growth or ecdysis, and their scaly investment remains in a condition similar to that which obtained when the Chalcid larvæ emerged from the egg. A host harbouring the larvæ of the parasite may be frequently recognised by the fact that the latter shows through the partially developed scale as a faint yellowish object. The *Lepidosaphes* continues to imbibe nourishment from the tissues of the food-plant, but it invariably dies as the result of the parasitism and, as a rule, long before it has become capable of depositing any ova. Although I have examined considerably over 1000 parasitic larvæ belonging to the two generations, I have never found more than one parasite in association with an individual host. In America, Le Baron states that he never met with more than two.

In working out the life-history of this species a practical difficulty confronts the observer, inasmuch as it is not possible to study the same individual specimen continuously through its life-cycle. This is sufficiently obvious when taking into account the fact that the host must be exposed by the removal of its scale. Also, in order to ascertain when the young parasitic larva has emerged from the egg a microscopic examination is necessary owing to its minute size. This entails cutting off the twig of the tree bearing it, and it has not been possible to keep the twig sufficiently fresh to enable the host to remain alive the requisite time necessary to support its parasite until the latter pupates. By examining a large number of specimens, however, a very close approximation to the truth can be arrived at.

The period spent in the larval condition varies from about twenty-three days to rather more than one month. In Cheshire the first young larvæ were observed on July 15th, 1915, and the earliest date pupæ were noted was August 12th. When fully fed the larva discharges the contents of the alimentary canal, no excreta having been voided previously. It then passes into a pro-nymph (or semi-pupa), which subsequently transforms into the fully formed pupa. The larva constructs nothing of the nature of a cocoon, and the pupa lies on its ventral surface beneath the host scale with its head directed towards the broad end of the latter. The period passed in the pupal stage averages from about twenty-one to thirty days, though it may be prolonged to as long as two months. The latter duration happened in the case of larvæ which were late in pupating, and a long period of cold and wet weather prevailed afterwards.

The Second Generation.—The perfect insects of the second generation usually make their exit into the outer world by pushing their way out from beneath the host scales. In some cases, however, the scale adheres with greater firmness to its resting surface, and under these circumstances the parasite effects its emergence by gnawing away with its mandibles a portion of the hinder end of the scale. The dorsal emergence holes seen in Text-fig. 5, with one exception, were not observed in connection with the second generation of the Aphelinus. In the case of material obtained from Kew (Surrey) the mussel scale was in a more advanced stage of development than in Lancashire and Cheshire. Here and there among the living mussel scales were, apparently fresh, empty scales perforated with the dorsal emergence holes of the parasite. Some of the perforated scales overlaid living scale insects, and I believe, in this particular instance, there was no doubt that all the hosts, both parasitised and unparasitised, were derived from the present year's parents.

It has been mentioned (p. 232) that the winged insects of this generation are markedly smaller than those of the preceding one, and it appears probable that the difference in size is mainly determined by the food supply. The first generation of adults spent some eight months in the larval condition, and subsisted upon the greater food supply afforded by the fully-grown adult hosts; whereas in the case of the second generation only about three weeks or one month is spent in the larval stage, and each larva has for its sustenance a single immature host averaging 1 mm. long. The latter when parasitised undergoes no further growth, and is only able to support itself and its parasite until the latter is about to pupate.

The average duration of life of the adult parasites is apparently very short, for when freshly emerged examples were placed upon twigs, which were kept moistened in a cool room, they failed to survive longer than five days. In Lancashire and Cheshire the first adult parasite appeared in the breeding-cages on August 26th in 1914 and August 31st in 1915; but in warm, sunny situations they commence to emerge at least one week earlier than the first-mentioned date. From the south of England (Plymouth) I have obtained evidence indicating that they commence appearing during the first week in August. The period of emergence covers about one month, and the latest date upon which any specimens were bred out was September 17th. A large number of examples failed to emerge at all, having died in the pupal stage. Altogether only fifty-one specimens were bred out from three localities, situated respectively in Devon, Lancashire, and Cheshire. Of these six were males, which appeared between August 26th and September 10th, 1914, from mussel scale obtained from Plymouth. Copulation was not observed, and the females are apparently parthenogenetic, as in the first generation.

The eggs of the parasite are laid on the fully grown, sexually mature hosts at the time when the latter have commenced to deposit their own ova, or a few days previous to that event. The scaly covering, only, is perforated in the act of oviposition, and the egg is placed on the body of the host, most usually on the dorsal surface. The young larva behaves, at any rate during the first period of its life, in a manner similar to that described for the first generation, and the nutriment afforded by the host is sufficient to support it until it has attained its full size towards the end of October or the beginning of November. The host by this time becomes completely exhausted and soon dies.

The parasitic larva, when disturbed or irritated, is capable of some slight movement, both the head and anal extremities admitting of a certain amount of protrusion and retraction. At times, also, a kind of slow "peristaltic" movement passes over the body from one end to the other, and is accompanied occasionally by a slight rotatory or twisting motion first to one side and then back again to the other. Under ordinary circumstances, however, the fully grown larva appears practically motionless, with the head end of the body somewhat retracted into the region which immediately follows.

During the winter and a portion of the following spring the larva hibernates beneath the covering scale of its dead host. Before pupation it discharges the contents of its digestive system as a series of dark brown, or black, fusiform bodies, very definite in both shape and size. They vary up to about eighteen in number, and average ·14 mm. × ·05 mm. in dimensions. They are found accompanying the pupa also, but the larvæ were never observed to evacuate the contents of the alimentary canal during earlier stages in their life. Very similar bodies have been noted by Quayle (1910, p. 399) in Aphelinus diaspidis How., and the habit of a single evacuation of excrementous material, at the end of the larval stage, is of frequent occurrence among the various groups of parasitic Hymenoptera.

A pre-pupal or pro-nymph stage (semi-pupa of Packard) follows that of the larva, and is of short duration. The insect then measures ·73 to about ·83 mm. in length, and ·35 mm. wide across the thoracic region. This stage is intermediate between that of the larva and pupa, and has been described and figured in the Chalcididæ by Bugnion (1890) for Encyrtus fuscicollis and by Miss Embleton (1904) for Comys infelix. It is also known in numerous other Hymenoptera. In the present species it is pale yellowish white in colour and enclosed in a definite cuticle; the appendages of the imago are already clearly defined, although in a less advanced condition than occurs in the pupa. The head is clearly marked off from the rest of the insect, the thorax less perfectly so, and there are only faint indications of segmentation in the abdomen.

The earliest date upon which the pupa was observed was May 10th, 1914, while some of the larvæ remained as late as June 30th before assuming the pre-pupal condition. On an average twenty-one to thirty days are spent in the pupa, though damp and cold weather may prolong the period for upwards of two months. No cocoon is constructed, and the pupa lies on its back beneath the scale with its head directed, in some cases anteriorly and in others posteriorly, with reference to its host.

While following up the life-history of the second generation the question arose as to whether the larvæ, after the death of the host, became predaceous upon the eggs of the latter. Some 365 parasitised hosts were examined at various periods, and the number of eggs found in association with them was recorded in each instance. The average was found to be 3·4 eggs per host (Table I). Further details are given in Table II, and it will be noted that in 109 of the hosts no

Table I.—Based on an Examination of 365 Parasitised Females of Lepidosaphes ulmi, indicating the Average Number of Ova which were found to be present.

Locality.	Dates of examination.	Parasitised hosts examined.	Number of ova present.	Average number of ova per female.
Oxshott (Surrey)	Feb. 24th–Mar. 1st, 1914	121	356	2·9
Bere Alston (Devon)	Dec. 1st, 1914	23	56	2·4
Holmes Chapel (Cheshire)	Oct. 28th–Nov. 11th. 1914	188	705	3·7
Holmes Chapel (Cheshire)	Feb. 17th, 1915	33	155	4·7
Totals		365	1272	3·4

Note.—The two counts made on material from Holmes Chapel were from two different branches of the same tree.

TABLE II.—Detailed Analysis of Preceding Table, showing the Number of Eggs present in each of the 365 Parasitised Hosts.

Locality.	Dates of observations.	Hosts examined.	Number of eggs present.																
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Over 15
Oxshott (Surrey)	Feb. 24th–Mar. 1st, 1914	121	42	6	20	15	14	6	5	3	3	1	2	1	—	—	2	—	1
Bere Alston (Devon)	Dec. 1st, 1914	23	10	2	3	4	—	1	1	1	1	—	—	—	—	—	—	—	—
Holmes Chapel (Cheshire)	Oct. 28th–Nov. 11th, 1914	188	52	15	27	17	19	15	7	10	3	8	2	—	3	2	3	—	8
Holmes Chapel (Cheshire)	Feb. 17th, 1915	33	5	4	6	2	4	2	1	1	2	1	1	—	1	—	1	1	1
Totals		365	109	27	56	38	37	24	14	15	9	10	5	1	4	2	3	1	10

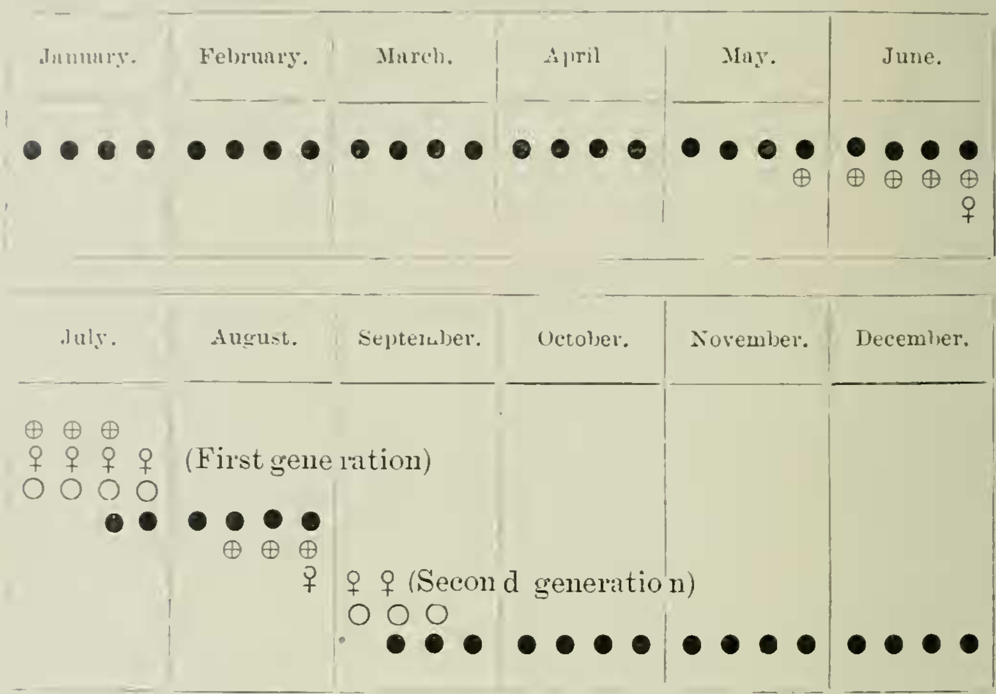
eggs were present, 56 hosts contained two eggs each, while only 74 hosts, or 20·2 per cent., contained more than five eggs apiece, the approximate reduction in the number of eggs, as compared with the average number laid by unparasitised hosts, being 91 per cent. This essential difference in the rate of increase appears to be due to either (a) the destruction of ova by the larval parasite, or (b) to the parasite inhibiting the egg-laying process, or (c) to a combination of both these factors.

With regard to the possibility of the ova being destroyed by the parasite, I may add that I have never observed the larvæ of mytilaspidis actually preying upon the eggs of its host, notwithstanding having examined over 500 parasitised scale insects for the purpose. On the other hand, Fitch (1885), Le Baron (1870), Howard (1881), the Duke of Bedford and Pickering (1906 and 1908), and others have published statements to the effect that the larvæ feed upon the eggs of their host. It is true that, after the destruction of the female mussel scale, the larval parasite is usually to be found in close proximity to the eggs, and frequently its head end is in contact with the latter, although on other occasions its posterior extremity was observed to be nearest the eggs. Furthermore, shrivelled eggs are of frequent occurrence beneath parasitised scales, suggesting that the larvæ of mytilaspidis are the causative agents. In this connection, however, it is noteworthy that shrivelled eggs and empty shells are also often to be met with among the healthy eggs of unparasitised scale insects, and their presence is not necessarily associated with that of the parasite. Several writers have recorded Acari as attacking the eggs of the mussel scale. Not infrequently, during the present investigations, they were found beneath scales containing both shrivelled and empty ova, and were responsible for the destruction of a certain number of them. In other cases no assignable cause could be discovered to account for the destruction of the eggs. If the larvæ of mytilaspidis are the primary agents entailing their destruction, it would be reasonable to expect to find eggs beneath parasitised scales to become gradually reduced in numbers as the season progresses. On the contrary, if reference be made to Tables II and III it will be seen that there is no evidence in favour of such a contention.

The evidence supporting the possibility of the reduction in the number of eggs being due to the parasite exercising an inhibitory effect upon oviposition is much more conclusive. Firstly, the food supply afforded by the adult host is sufficient to enable the larval parasite to attain its full size by the end of October or beginning of November. A series of measurements made upon larvæ the following spring indicated that no further increase in their dimensions appear to take place. Secondly, it is noteworthy that over 27 per cent. of 188 parasitised hosts examined between October 28th and November 11th, 1914 (Table II), sheltered fully grown larvæ of the Aphelinus, but no eggs were present, and the hosts were dead in every case. Twenty of these larvæ were kept under laboratory conditions, and nine of them pupated the following spring, while the remaining eleven were attacked by fungi and died. It appears, therefore, that the eggs are not essential for the nutrition of the parasite. Also, if the latter does not inhibit oviposition, we have to assume that each parasite destroyed in these instances an average of thirty-seven eggs during less than one eighth of the span of its larval existence, which is beyond the bounds of probability. Furthermore, no shrivelled remains of eggs were found beneath the scales in any instance, which might indicate that such destruction had taken place.

It may be claimed, therefore, that one of the effects of the parasitism is to inhibit oviposition, and this fact is the primary cause of the essential reduction in the number of eggs found in association with affected hosts. It is not unlikely that the parasitic larvæ may devour a small number of eggs, but quite an inadequate quantity to bring about the observed reduction in their numbers.

Summary of the Life-History.—The complete life-history, based upon observations conducted in Lancashire and Cheshire during the years 1913–15, may be summarised in a symbolical form as follows :



○ = egg; ● = larva; ⊕ = pupa; ♀ = adult (female).

In this diagram it will be noted that the signs are grouped in fours, representing four weeks to each month. As an example, it will be seen that the earliest date the adults of the first generation are likely to occur is the last week in June, and they are to be met with up to the last week in July, and so on.

Economic Status as a Parasite.

The earliest writer, with whom I am acquainted, dealing with the economic status of the Aphelininæ is Le Baron (1870, p. 362). This observer states that A. mytilaspidis was destroying in Illinois in 1870 twice as many of its host as all other agencies together. During the winter of 1871–72 he transported half a dozen scale infested twigs, known to be parasitised, from Geneva (Illinois) to Galena, where the parasite seemed to be lacking. These branches were fastened to infected trees in three different orchards. At the end of the season evidence was obtained which tended to show that the parasites had established themselves. No exact details of the experiment were given, and it cannot be regarded as one of very much value. Riley (1873, p. 90) adds: "To colonise the parasite all that is necessary is to tie such parasitised twigs on to trees which it is required to protect, and the microscopic flies will issue at the proper season and carry on their good work." In Canada, Fletcher (1904, p. 188) states that the parasite is sometimes so abundant that it destroys more than half of the scale insects present, and that it has occurred in all parts of Canada, but never seems to remain long in any district. Howard (1907, p. 69) states that the Aphelininæ are by far the most important parasites of the Diaspinæ (to which the mussel scale belongs), and that in the twelve years which have elapsed since the publication of his 'Revision' their economic importance has become even more evident.

The Duke of Bedford and Pickering (1906, p. 7; 1908, p. 35) mention that larvæ of this insect are often found in large numbers under the scales, feeding on the eggs. They remark that they are very localised, and that an abundance of the food supply does not appear to ensure the spread and multiplication of the Chalcid, which may be absent on one branch and plentiful on another. Quaintance and Sasscer remark (1910, p. 6) that parasitic Hymenoptera are often efficient enemies of the mussel scale, and in some localities they apparently hold it in check. They quote seven species of parasites of this insect, but give no details with regard to their relative efficiency. Sherman (1913, p. 15) mentions that in the State of North Carolina it is known that the parasites of Lepidosaphes ulmi are very actively at work, and that in some cases at least they are a decided factor in holding that insect in check. In a foot-note he adds that specimens of parasites bred from infested twigs and submitted to Washington proved to be exclusively A. mytilaspidis. Cæsar (1914, p. 30) states that in some localities in Ontario as high as 50 per cent. or more of the scales have emergence holes of this parasite, and though it does not destroy all the eggs beneath a scale, it must be of considerable aid in keeping down the rate of increase. Additional references to its occurrence as a parasite are to be found, especially in North American literature, but as they do not contain any further information it is not necessary to deal with them here.

The value and efficiency of any given parasite from the economic standpoint depends upon numerous factors. The all-important test is afforded by ascertaining the extent by which it reduces the normal rate of increase of its host. In so far as I am aware, only two attempts have been made to apply this criterion in the case of *Aphelinus mytilaspidis*. Le Baron (1870, p. 362) states that from four twigs infested with mussel scale of that year, obtained from four different apple trees in two gardens remote from each other, he found the following:

Whole number of scales	330
Round holes made by *Chalcis* fly . . .	116
Larvæ of the *Chalcis* under the scales . .	95
Ragged holes made by Coccinellidæ . .	7
Shrunken and discoloured eggs . . .	81
Acari found under the scales	4
Scales containing eggs not damaged . .	27

It will be seen, therefore, the *Chalcis* (e.g. *Aphelinus mytilaspidis*) attacked 63·9 per cent. of the total number of the host.

From mussel scale collected from different localities in Kane and Du Page counties he obtained the following results:

Whole number of scales examined . . .	844
Number destroyed by Chalcids . . .	533
Destroyed by Acari and unknown causes .	234
Scales containing more or less eggs . .	57

In this case it appears that *A. mytilaspidis* attacked 63·1 per cent. of the total number of scale insects.

Sherman (1913, pp. 16–17) gives a table showing that out of a total of 584 scales examined during March and April, 1913, from six different localities, 56 showed attacks by parasites, the greater number of which appeared to be A. mytilaspidis. This gives 9·6 per cent. as the average number killed by the Chalcid. The obvious criticism of the counts made by these two observers is that they deal with too small a number of the host to be regarded as being really representative. From experience gained during the past two years, I have been able to satisfy myself that estimates of parasitism based upon small numbers of counts are often misleading. This is owing to the fact that the parasite, in virtue of its limited powers of migration, is extremely localised, even with reference to a single branch of a tree. One small portion of a branch may be heavily parasitised and the remainder contain no parasites whatever.

The practice of searching for the emergence holes of the parasite is at once the readiest method, and the easiest to carry out in so far as the second generation is concerned. This method of estimation, however, is open to the objection that it is not usually possible to distinguish between the scales of the present and previous years, as the latter may adhere to the bark of the twigs for several successive seasons. Furthermore, unparasitised scales are liable to fall off more readily owing to the practice of the young larvæ, as they emerge, of pushing their way out from beneath the scales, thus loosening the latter in the process. It will, therefore be evident that the proportion of parasitised to unparasitised scales is liable to appear greater than is actually the case. The most reliable method is to confine the examination exclusively to living specimens, and to turn them over by the aid of a needle under a binocular microscope, recording at the same time the number which harbour the Aphelinus larvæ beneath them. This method was partially resorted to by Le Baron and Sherman, and has been adopted throughout the present investigation for both generations of the parasite. In the case of the first generation, material was obtained from fewer localities than had been anticipated. This was largely due to the inspectors of the Board of Agriculture being occupied with additional duties owing to the European War, and were unable in consequence to give the necessary assistance in procuring it. Also, at this time of the year the trees are in fruit, which offers an obvious difficulty to the removal of branches therefrom. Scale infested branches, containing parasites of the first generation, were obtained during August, 1915, from three localities, and the average parasitism was found to be 4·1 per cent. The results obtained are tabulated as follows:

Locality.	Hosts examined.	Hosts parasitised.	Percentage of parasitism.
Kew Gardens (Surrey)	583	27	4·6 per cent.
West Didsbury (Lancashire)	1853	104	5·6 per cent.
Holmes Chapel (Cheshire)	1491	33	2·2 per cent.
Totals . . .	3927	164	4·1 per cent. (Average parisitism).

In the case of the second generation an abundance of material was secured during the years 1914 and 1915, and the parasitism was found to vary from ·1 per cent. to 11·2 per cent. in different localities. The average parasitism, based upon an examination of 14,155 examples of the host, worked out at 3·2 per cent. (*vide* Table III), and in only three localities did it exceed 2·2 per cent.

The first generation of the *Aphelinus* attacks the mussel scale in the early stages of the latter. The result of the parasitism is complete, for the affected hosts invariably die in consequence. The attacks of the second generation of the parasite occur when the mussel scale is sexually mature and commencing to lay its eggs. As previously mentioned (p. 258), although each affected host is killed, an average of 3·4 of its eggs remain to help to maintain the species, and in this respect, therefore, the result of the parasitism is only

Table III.—Showing the number of *Lepidosaphes ulmi* attacked by *Aphelinus mytilaspidis*, based on material obtained from various parts of England.

Locality.	Dates of examination.	Hosts examined.	Hosts parasitised.	Percentage of parasitism.
Plymouth (Devon)	Oct. 23rd–26th. 1914	1080	3	·2 per cent.
Bere Alston (Devon)	Dec. 1st. 1913	1020	23	2·2 per cent.
Oxshott (Surrey)	Feb. 24th–Mar. 1st. 1915	1076	121	11·2 per cent.
Slough (Glos.)	May 30th. 1914	230	23	10 per cent.
Aspley Guise (Beds.)	April 29th-May 10th, 1914	2716	27	1 per cent.
Meatham (Leices.)	May 19th, 1914	1025	9	·5 per cent.
Newport (Salop.)	May 5th, 1914	1000	4	·4 per cent.
Northen Etchells (Ches.)	May 15th. 1914	122	1	·8 per cent.
Northenden (Ches.)	Oct. 23rd, 1914	380	5	1·3 per cent.
Holmes Chapel (Ches.)	Oct. 28th–Nov. 11th. 1914	2016	209	10·3 per cent.
Holmes Chapel (Ches.)	Nov. 6th–10th, 1914	2027	4	·2 per cent.
Holmes Chapel (Ches.)	Feb. 17th, 1915	1463	33	2·2 per cent.
Totals		14,155	462	3·2 per cent. (Average parasitism)

Note.—The Holmes Chapel material was obtained from three different localities situated less than two miles from each other.

partial and not complete. The effect of one year's parasitism on the natural rate of increase of the host can be more easily represented by taking a hypothetical instance than by any other method. According to the foregoing investigations, out of every 1000 examples of the mussel scale forty-one are destroyed by the larvæ of the first generation of the Aphelinus. The remaining 959 hosts become sexually mature and commence laying their eggs. They are then attacked to the extent of 3·2 per cent. of their numbers by the larvæ of the second generation of the parasite—in other words, thirty-one examples will be affected. Now, taking the actual number of eggs laid by each individual host as being 37·2 (vide p. 221), the number laid by 928 examples will be 34,522, while the thirty-one parasitised individuals will among them lay 105 eggs (vide p. 258). The total number of eggs laid by the hosts will, therefore, be 34,627. But 1000 unparasitised hosts lay on an average 37,200 eggs, so that the net result of a year's parasitism will be a reduction of 2573 in the number of eggs laid, or 7 per cent.

It is not unlikely that in very favourable seasons, more especially in the south of England, this parasite may be more abundant and entail a greater reduction in the rate of increase of its host. Even allowing its effectiveness to be increased by 100 per cent., its capability as an inhibiting agent would not justify special measures being taken to attempt its preservation and increase, since the net results of its parasitism would be far below those of the most effective insecticides. It is noteworthy that hyperparasites do not appear to be a factor entering into the economy of A. mytilaspidis. Not a single hyperparasite was reared during these investigations, and none have been recorded as enemies of this species. Four important factors appear to be responsible for the relatively low degree of efficiency of this parasite: firstly, its extremely limited powers of migration, which prevent it from becoming quickly disseminated in the event of any local increase in its numbers; secondly, its relatively low fecundity; thirdly, its marked susceptibility to the influence of unfavourable climatic conditions; fourthly, the the fact that the effects of its second annual generation of parasitism are only partial and incomplete.

Summary of Conclusions.

(1) Aphelinus mytilaspidis Le Baron, a Chalcid

belonging to the sub-family Aphelininæ, is the principal parasite of the mussel scale (*Lepidosaphes ulmi* L.) in England. Material obtained from various parts of the country indicates that it is generally distributed. Detailed descriptions are given of the insect in all its stages.

(2) The parasite passes through two generations in the year, and the adults consist almost entirely of females. Out of over 750 bred specimens only 10, or approximately 1 per cent., were males. Parthenogenesis is definitely proved to occur, and is probably the usual method of reproduction.

(3) The adult insects seldom resort to flight, and have extremely limited powers of migration. They are positively phototropic, but exhibit no marked response to geotropism.

(4) In the first generation the adults appear in greatest frequency between the third week in June and the middle of July. The female lays a single egg on the dorsal or ventral surface of the body of the immature host, only the scaly covering of the latter being perforated. The newly hatched larva closely resembles the fully grown stage in form, and during larval life the insect is an ectoparasite of its host. The second generation of adults mostly appear between the middle of August and the first week in September. They parasitise the sexually mature hosts, and the resulting larvæ hibernate through the winter, giving rise to the first generation of adults of the following year.

(5) The results of the first generation of parasitism are complete, the affected hosts invariably dying in consequence. In the second generation of parasitism the affected hosts usually deposit a small number of eggs before succumbing; its results, therefore, are partial and incomplete. The parasite exercises an inhibitory effect upon oviposition, the essential reduction in the number of eggs not being primarily due, as stated by previous observers, to their destruction by the *Aphelinus* larvæ.

(6) Assuming that every 1000 hosts lay on an average 37,200 eggs, the net results of a year's parasitism entails a reduction of about 2600 in the number of eggs laid, or 7 per

cent. The efficiency of the parasite, therefore, is far below that of the most effective insecticides. This is primarily due to four factors: (1) its extremely limited powers of migration; (2) its relatively low fecundity; (3) its marked susceptibility to the influence of unfavourable climatic conditions; (4) the effects of the second annual generation of parasitism being only partial and incomplete.

September, 1915.

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EXPLANATION OF PLATES 19 AND 20.

Illustrating Dr. A. D. Imms' paper on "Observations on the Insect Parasites of some Coccidæ.—I: On Aphelinus mytilaspidis Le Baron, a Chalcid Parasite of the Mussel Scale (Lepidosaphes ulmi L.)."

PLATE 19.

[With the exception of Fig. 15, the drawings were made from the female imago.]

Fig. 1.—Adult female of Aphelinus mytilaspidis Le Baron. × 50.

Fig. 2.—First maxilla. × 533. *a.* Lobe of maxilla, possibly representing an undivided galea and lacinia. *b.* Basal portion, probably representing an undifferentiated cardo and stripes. *mx. p.* Maxillary palp.

Fig. 3.—Second maxillæ (labium) viewed from the dorsal or pharyngeal aspect. × 900. *l.* Ligula. *l. p.* Labial palp. *m.* Mentum.

Fig. 4.—Right mandible. × 650.

Fig. 5.—Left antenna viewed from the ventral surface. × 220. *a. s.* Socket of antenna. *b.* Basal joint. *p.* Pedicel. *s.* Scape.

Fig. 6.—Dorsal aspect of the thorax. × 180. *f. v.* Base of the right fore-wing. *h. w.* Base of the right hind-wing. *i. t.* Propodeum. *mlm.* Mesoscutellum. *mn.* Metanotum. *mtn.* Mesoscutum. *p. n.* Pronotum. *pr.* Parapsides (right). *scp.* Scapula (left).

Fig. 7.—Submarginal vein of the left fore-wing. × 440.

Fig. 8.—Submarginal vein of the left hind-wing. × 440.

Fig. 9.—Right anterior leg. × 250. *f.* Femur. *t. s.* Tibial spur (or spine).

Fig. 10.—Left middle leg. × 250. *f.* Femur. *t. s.* Tibial spur (or spine).

Fig. 11.—Right posterior leg. × 250. *f.* Femur. *t. s.* Tibial spur (or spine).

Fig. 12.—Ventral aspect of the ovipositor and associated parts. From a preparation stained with a 1 per cent. aqueous solution of fuchsin and mounted in glycerine. × 235. *ap.* Appendage of right inner plate. *b. pl.*$_1$ Basal portion of the median rib of the left inner plate. *c. sh.* Transverse chitinous support of the sheath of the ovipositor. *pl.*$_1$ Inner plate (left). *pl.*$_2$ Outer plate (left). *r.*$_1$ Median rib of left inner plate. *r.*$_2$ Median or basal portion of supporting ribs of the left outer plate. *sh.* Sheath of ovipositor. *sh.*$_1$ Thickened rim or edge of the left arm of the sheath of the ovipositor. *s. pl.*$_1$ Chitinised area of left inner plate, by means of which the latter articulates with the transverse support (*c. sh.*) of the ovipositor sheath. *sty.* Stylets. *sty.*$_1$ Curved arm of the left stylet. *t. p.* Supporting plate.

Fig. 13.—Abdominal sensory plate of the left side. From a preparation stained with a 1 per cent. aqueous solution of fuchsin and mounted in Canada balsam. × circa 900.

Fig. 14.—Apex of the sheath of the ovipositor seen from the right side. From a specimen mounted in Canada balsam. × 1000.

Fig. 15.—Ventral aspect of the penis and associated parts. From a preparation stained with 1 per cent. aqueous solution of fuchsin and mounted in Canada balsam. × 680. *b. p.* Basal portion. *c.* Clasper (left). *p.* Penis. *p. p.* Apical papillæ of the penis. *r. p.* Rod-like support (left). *v. p.* Ventral papilla (left).

PLATE 20.

[With the exception of fig. 23, the drawings were made from different stages in the first generation of the Aphelinus.]

Fig. 16.—Pupa (female) of Aphelinus mytilaspidis, seen from the ventral aspect. From a living specimen. × 95. *an. s.* Antennal sheath. *f. w. s.* Sheath of fore-wing. *h. w. s.* Sheath of hind-wing.

$l._1s$. Sheath of anterior leg. *$l._2s$.* Sheath of middle leg. *$l._3s$.* Sheath of posterior leg. *lm. s.* Sheath of labium. *md. s.* Sheath of mandible. *mx. s.* Sheath of 1st maxilla. *ov. pl.* Developing plates of ovipositor *st. pl.* Developing plates of abdominal sterna.

Fig. 17.—A fully-grown larva, dorsal aspect. From a living specimen placed on a dark background and viewed with reflected light. The larva is seen extended to its fullest extent. × 50.

Fig. 18.—A fully-grown larva, dorsal aspect. From a living specimen placed in normal salt solution and examined under a cover glass. Slight pressure has been applied to the cover glass, extending the larva to its fullest degree. The course of the fore and hind gut is represented by the double series of dotted lines. × 120. *a. c.* Anterior tracheal commissure. *d. t.* Dorsal segmental tracheal branch. *f. b.* Fat body. *md.* Mandible. *m. g.* Mid-gut. *mo.* Mouth. *m. t.* Main lateral tracheal trunk. *p. c.* Posterior tracheal commissure. *sp.* Spiracle. *t. t.* Transverse segmental tracheal trunk leading to spiracle. *v. t.* Ventral segmental tracheal branch.

Fig. 19.—Ventral aspect of the head of a fully-grown larva. × 950. *c. s.* Supporting skeleton of head. *mo.* Mouth. *md.* Mandible. *m. s. d.* Median salivary duct. *r. s. d.* Salivary duct from gland of the right side. *ph.* Pharynx. *pp.* Ventral cuticular papillæ.

Fig. 20.—A youngest stage larva, about an hour after emergence from the egg. From a living specimen mounted in salt solution and viewed under a cover glass. × 630. *a. c.* Anterior tracheal commissure. *md.* Mandible. *m. g.* Mid-gut. *m. s. d.* Median salivary duct. *m. t.* Main lateral tracheal trunk. *p. c.* Posterior tracheal commissure. *sp.* Spiracle. *t. t.* Transverse segmental tracheal trunk leading to spiracle.

Fig. 21.—Ovum, about six hours after being laid by a parthenogenetic female. × 550.

Fig. 22.—Right ovary of a parthenogenetic female insect. The latter had deposited eight ova, and the ovaries were then teased out in normal salt solution. The preparation was afterwards treated with acetic acid, but was unstained. × 225. *$e._1$, $e._2$, $e._3$* Different stages of developing ova. *e. c.* Egg chamber with young oocyte surrounded by follicular cells. *g.* Germarium. *n. c.* Nutritive chamber. *od.* Oviduct. *w. o.* Wall of ovariole.

Fig. 23.—Dorsal view of a young adult female Lepidosaphes ulmi parasitised by a larva of Aphelinus mytilaspidis (second generation). The latter is in an early stage of development, and measured ·25 mm. in length. Drawn from the living objects, after removal of the scale investing the host. × 35. *p.* Parasitic larva.